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ENGINEERING DESIGN FILE

PROJECT NO. 22901

TSF-09/18 V-Tanks Remediation Pump Seal Evaluation

Idaho Cleanup Project

The Idaho Cleanup Project is operated for the
U.S. Department of Energy by CH2M ♦ WG Idaho, LLC

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1. Title: TSF-09/18 V-Tanks Remediation Pump Seal Evaluation

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The V-Tank centrifugal consolidation pump(s) P-1 & P-2 used to support the Tan V-Tank Project have experienced several mechanical seal failures. The V-Tank Consolidation pumps recirculate "radioactive slurry" as a means to achieve a homogeneous mixture within the consolidation tanks. It is recommended that the consolidation pumps be replaced with air operated double diaphragm to minimize leakage risk associated with centrifugal pump seals.

6. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

	R/A	Typed Name/Organization	Signature	Date
Performer/ Author	N/A	E. L. Baker, P.E.	Edward T. Baker	11/22/05
Technical Checker	R	Randy Eastman, P.E.	Randy Eastman	11/22/05
Approver	A	R. R. Heyrend, P.E.	Randy R. Heyrend	11/22/05
Design Project Engineer	A	Mark E. Bodily	Randy Heyrend for Mark Bodily	11/22/05
Program Project Engineer	Ac	David F. Nickelson	Randy Heyrend for David F. Nickelson	11/22/05
Doc. Control	AC	Tara Swensen, Doc Control	Tara Swensen	12-15-05

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PROFESSIONAL ENGINEER
REGISTERED
3994
11/22/05
STATE OF IDAHO
EDWARD L. BAKER

Purpose

The V-Tank centrifugal consolidation pump(s) P-1 & P-2 used to support the Tan V-Tank Project have experienced several mechanical seal failures. These seal failures have resulted in project schedule delays, additional costs, and the potential release of radioactive fluid and contaminates. The V-Tank Consolidation pumps recirculate "radioactive slurry" as a means to achieve a homogeneous mixture within the consolidation tanks. The purpose of this EDF is to provide recommendations for the continued use, repair, or replacement of pumps P1 & P2, review the use of pumps P1 & P-2 for V-Tank pump activities, and if necessary recommend an alternative pump type more suitable for the pumping application. The centrifugal pump(s) where selected based on the analysis and recommendations of EDF-4602. Drawings 628467,628468 and 628489 identify pump location and arrangement. Attached as Appendix 1., is the technical and vendor information with respect to the centrifugal pump(s) P-1 & P-2.

Centrifugal Pump Seal Failure History

On July 7, 2005 operations personnel noticed loud noises coming from the Consolidation Pump Skid area at 1255. Pump P-1 was running and pump P-2 shut down as a result of a tripped electrical breaker. Operations shut down pump P-1 and then restarted both pumps. Later that afternoon at 1430 they recorded that "Seal Pot" pressure for pump P-1 had dropped to 0 psig. No leakage was noted from P-1 pump seals, however the seal pot pressure of 0 psig is an indication of failure of the inner mechanical pump seal. At 1616 pump P-2 tripped the electrical breaker again. Pump P-1 was shut down, both pumps P-1 and P-2 were reset and re-started.

On July 8, 2005 at 1410, operations personnel recorded P-2 pump was running with no discharge pressure. A little while later they recorded P-1 pump was losing pressure and running hot (at elevated temperature).

On July 11, 2005 maintenance personnel determined that the P-2 pump flexible coupling had a sheared insert. Further investigation of the P-1 and P-3 pumps found that coupling inserts on these pumps were distorted due to excessive torque.

On July 12, 2005 all three coupling inserts on the pumps were replaced. The facility system engineer (Garry Anderson) and Project Field Engineer (Paul Sloan) consulted with the Gould pump vendor and determined that the pumps, as installed, were operating out of optimal pump curve parameters. It was suggested by the system engineer and vendor that the pumps be operated with their discharge valves throttled to maintain approximately 65 psig discharge pressure. This would limit flow through the pumps and keep them at their optimum operating range on the pump flow curve. Initial evaluation relative to changing the pump(s) impeller diameter took place at this time. Late in the evening (2350) Pumps P-1 and P-2 were making noise. The pumps were stopped and restarted.

Operation logs indicates that operations personnel had noted that pump P-1 experienced excessive vibration and loss of suction numerous times from July 13, 2005 through July 18, 2005. During this period of time, it appears that P-1 pump ran while cavitating possibly for several hours during this time period.

On July 18, 2005 it was noted (2000) that the Terri-Towel under the P-1 seal area was showing a black line under the seal indicating early signs of outer seal failure. About six hours later, on July 19, 2005 at 0210, P-1 pump discharge pressure was running 0 to 5 psig and spray was noted coming from the seals area of the pump indicating outer seal failure. Pump P-1 was shut down and isolated. P-2 pump continued to run for the most part through July 27, 2005. It was determined by the system engineer to replace pump P-1 and P-2 impellers with a smaller diameter impeller, enabling the pumps to run at optimum pump curve parameters without having to throttle the pump discharge valves.

On August 2, 2005 repairs were made to pump P-1 that included; replacing the failed seals and installation of the smaller diameter impeller. These repairs were completed on August 3, 2005. Seals and impeller replacement were completed on P-2 pump August 4, 2005.

After pump P-2 seal was replaced, operations noted on August 6, 2005 (0200) that the pump P-2 seal pot pressure was decreasing. Pressure had decreased from the 50 psig initial pressure placed on the seals the morning August 5, 2005 to 0 psig at 1215 on August 6, 2005. After consultation with the vendor (C. H. Spencer, and Co) it was determined that the rebuilt seal was not operating correctly. The remaining rebuilt seals stored as project spares were taken by the vendor, rebuilt, pressure tested and sent back to us. Pump P-2 seals were replaced with new rebuilt and tested seals on August 15, 2005.

Pumps P-1, P-2, and P-3 were run intermittently from August 15, 2005 to August 20, 2005 when it was noted at 0615 that seal pot pressure on P-2 had decreased to 24 psig indicating inner seal failure. At 1415 an attempt to start P-1 pump failed as no discharge pressure could be obtained, indicating a blocked suction line on the pump. At 1500 another attempt was made to start pump P-1 with the same results. At 1655 a third attempt to start pump P-1 was made and was successful, the pump registered 15 to 17 psig discharge pressure. The pump was left running. At 1800 it was noted the P-1 Pump seals had a black spray emanating from them indicating total seal failure. The pump was shut down and isolated.

On August 21, 2005 at 0400 P-2 pump had 0 psig seal pot pressure and a clear liquid spray coming from the seals area indicating total seal failure. Pumps were isolated and shut down.

Centrifugal Pump Seal Failure - Modes

Centrifugal pump mechanical seal failure can result from numerous causes. A detailed discussion on mechanical seal failure is beyond the scope of this report. However, listed below are the most common causes of seal failure:

Low Flow
Air Entrainment
Shaft misalignment
Bent Shaft
Worn Bearings
Unbalanced impeller
Cavitation
Vibration
Incorrect seal application
Material incompatibility

Several failure modes are concerns with the V-Tank centrifugal pump operations. It is highly likely that pump cavitation occurred in pumps P-1 & P-2 during pumping operations. Pumps P-1 & P-2 experienced vibration caused by throttling of valves and also slugging of the pumped fluid. Consolidation pump P-3 has not experienced a seal failure and appears to be operating satisfactorily. The operation of pump P-3 is somewhat different from pumps P-1 & P-2 in that it has been pumping water, not a slurry/sludge fluid.

Evaluation of Pump P-1 & P-2 Seal Failure

CWI Engineering contacted the centrifugal pump mechanical seal manufacturer (John Crane Company) to assist in the determination of the cause of mechanical pump seal failures for pumps P-1 & P-2. CWI engineers had several technical discussions with Dano Shaw (503-639-0700) product engineer for John Crane, who provided technical expertise and assistance. First, it was determined that based on the seal type and part number the mechanical seal was indeed the correct seal for the pumping application (slurry/sludge), as recommended by the pump manufacturer Gould Pump Company. Second, the specific type seal failure could not be determined conclusively because the seal would have to be physically removed and disassembled, removal of these seals are not practical due to radioactive contamination. Because the specific seal failure mode could not be determined, Dano Shaw made several recommendations to enhance mechanical seal reliability, these include:

1. Modify mechanical seal from the John Crane Company "standard configuration" to an "optional" configuration that will provide better seal cooling. The particular seal used in the pumping application is Silicon Carbide on Silicon Carbide seal surface, this material combination produces more heat then a standard Silicon Carbide/Carbon, and thus it requires better cooling.
2. Utilize propylene glycol as the heat transfer fluid circulated in the stuffing box in lieu of water. Propylene Glycol is a better lubricating fluid for the mechanical seal and thus reduces seal heating.
3. Maintain seal stuffing box pot fluid pressure of around 75 psig. The pot pressure needs to be maintained continuously to prevent micro particles from getting in between the seal faces, any pressure below the stuffing box pressure will allow particulate migrate into the seal face and reduce the seal life.
4. Utilize a seal flush on the pump side. The seal flush is an optional feature that protects the seal when pumping slurries. The seal flush protects the seal by introducing a clean fluid at the seal/pump shaft interface.

Based on the above recommendations CWI Engineering is exploring the necessary means to implement the modifications to pumps P-1 & P-2. It is important to note that John Crane Company supports the use of the specified mechanical seals and application as installed in P-1 & P-2., as long as the pump are operated within their respective operating/performance curves.

Item 4 listed above was identified as a potential problem, when P1 and P2 were disassembled for replacement of the failed seal. It was observed that a build-up of solid material had occurred in the area behind the pump seal chamber adjacent to the mechanical seal. The type of seal chamber supplied on the pumps is a "Taper Bore" seal chamber (Appendix 1.,Figure 1) which is generally used when pumping fluids with less than <10% suspended solid, which was the original design criteria for pump selection. However, actual fluid properties appear to have more than 10% suspended solids, in which case the recommended seal chamber is a "Big Bore" seal chamber (see Appendix 1., Figure 2 & 3) utilizing a machined bushing with 0.003 clearance between the shaft and the seal. A clean water flush is used behind the seal chamber to keep the solids form contacting the seal. Based on Appendix 1, Figure 4.37 the estimated water usage is:

GPM = F x L x O.D. (Shaft) = (0.16) x (1.4) x (1.75) = 0.39 gpm

F = flow factor from graph (0.003")	= 0.16
L = bushing length factor	= 1.4
O.D.	= 1.75

As previously stated, pump cavitation appears to have been experienced by both P-1 & P-2. The cavitation is typically a result of pump suction line blockage and discharge valve throttling, moreover the pump(s) appear to have been operating at less than optimum point on the pump curve due to increase system resistance. Cavitation creates pump vibration that results in seal chatter, a contributor to seal failure because the seals "bounce" open and allow micro particles to migrate between the seal services.

Several other issues have been identified as concerns with the pump system, (1) the actual amount of pumped solids in the system at any given time appears to be greater than the 7-10 % originally designed for, and (2) when pumps are not running the solids settle out in the pump suction lines and bottom of the tanks. This poses a significant challenge for continuous pump operation that will minimize pump/shaft vibration, and reduce pump cavitation. The pumps operated in a condition that was not anticipated during the initial pump selection.

Centrifugal Pump Repair Recommendations

One method commonly used to reduce pump cavitation is to install Variable Frequency Drive (VFD.) VFD's allow centrifugal pumps to operate at user defined pump speeds, thereby providing operations with a flexibility to adjust the pumps to the operating characteristics required for a particular application. In addition, microprocessor controller can be used with VFD's to monitor and control the pumps operating characteristics as necessary to provide save and reliable pump operation. It is recommended that a microprocessor controlled VFD be installed on each centrifugal pump for continued operation.

It's also recommended that a means to back flush the pump suction line prior to pump operation be installed in the suction line piping. The flush line would be used prior to starting a pump by injecting air thru the suction line and purging any solids may accumulate when the pump is off.

Other operational measures should include minimizing pump cycling, and starting the pump with the discharge valve open. Reduce pump operations that increase pump vibration It's also recommended that the modifications as described by the pump seal manufacturer be implemented for continued operation the centrifugal pumps P-1 & P-2.

Pump Evaluation and Comparison

In order to determine a path forward, a comparison of several different pump types was performed. This comparison evaluated pumps for use in the current sludge/slurry application. The evaluation is a result of the centrifugal pump seal failures. It's believed that the increase in pump solids is a contributor of centrifugal pump seal failure, and that the probability is high that another seal failure could occur. The high solids content of the fluid adds a higher factor of complexity to the system operation for recirculation and homogenization of the slurry. The intent of this evaluation is to recommend an approach that would accomplish the program objectives and avoid excessive downtime due to pump failure.

To reduce the size of pumped solids, inlet screens were installed at the tank inlets to strain particles larger than .25 inches from entering the T Tanks, however, the inlet screens were not used initially and it's likely that some debris up to ½" size entered the system. This discussion presents a new recirculation pump selection and the basis for the recommendation.

Attached as Appendix 3, is a table that lists the various types of pumps evaluated and the comparisons between them. Key comparison parameters were determined through project, engineering, and vendor discussions. The most difficult operating characteristic of the system is high solids concentration which includes occasional solid slugging. The evaluation included the existing Goulds 3196 Centrifugal pump (for comparison against existing). Other pump types evaluated included Vortex pumps, Double Diaphragm pumps, and single screw rotary pumps. Each of these pump types have the capability to receive high concentrations of solids in excess of 10 %.

A vortex pump is designed for high solids loading, as shown in the attached table. A typical horizontal vortex pump impeller is usually recessed out of the flow stream to minimize wear from the solids. However, since it requires a rotating shaft to drive the impeller, a shaft seal must be used to contain the process fluid. The main disadvantage of this pump is its inability to run long periods with a blocked flow and low pump efficiency.

The single screw rotary pump inability to operate with blocked flow is cause for elimination. Damage to the pump internals can occur within a short time if suction flow is choked.

Operating parameters that are of the greatest concern are addressed by air driven Diaphragm pumps. Blocked flow is not a problem for this type of pump and blocked flow does not initiate a pump failure. The pump can accept solids up to 2" in size with up to 70% solids concentration. Materials that are compatible with the process fluid are also available. There are no seals to deal with thus ensuring that no additional flush water is required and minimal interface to the control system is required. The double diaphragm pump is recommended for the current pumping application.

Conclusion

CWI Engineering concludes that the use of centrifugal recirculation pump P-1 & P-2 is correct for the application, based on the original selection criteria and design requirements. Similar centrifugal pumps are routinely used in sludge/slurry applications with excellent results. CWI Engineering also concludes that by implementing recommendations as discussed above, the possibility of another mechanical seal failure is reduced. The installation of VFD's alone would significantly reduce the probability of seal failure. In addition, installing a micro-processor controlled "pump smart" system would actively monitoring pump operation and automatically control pump speed while providing system flexibility to operate in a continuously changing application.

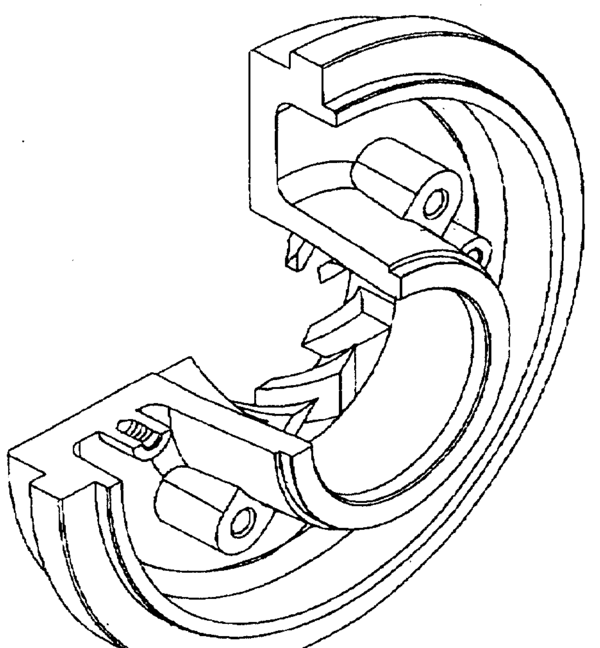
However, based on the current mode of operations and the solid(s) content of the fluid, it is recommended that centrifugal pumps P-1 and P-2 be replaced with a more robust pump. The high solid content of the slurry lends itself to slugging which most likely has damaged pump P-1 and P-2. The seal flush system for the centrifugal pumps as discussed is not feasible due to the amount of water usage.

It is recommended that pumps that air operated Diaphragm Pumps. Diaphragm pumps be used to provide a more reliable system when pumping fluids with high solids content as discussed above.

APPENDIX 1

Figure 1

TaperBore™ *PLUS* Seal Chamber (PATENTED! No. 5,336,048)



Also, designed specifically for mechanical seals. This revolutionary patented seal chamber design provides the best seal environment for single mechanical seals on services with or without solids, air, or vapors. The TaperBore™ PLUS completely reconfigures the flow pattern in the seal chamber. The result is that solids entry into the mechanical seal mounting area is minimized. If solids do reach the seal area they are directed away from the seal faces eliminating seal failures due to solids packing the seal spring or bellows and/or solids impingement on seal faces. Air and vapors are efficiently removed eliminating dry running seal face failures. Last, the flow in the TaperBore™ PLUS assures efficient heat removal (cooling) and lubrication of seal faces. Seal faces are continuously flushed with clean liquid. Extended seal and pump life with lower maintenance costs are the bottom line results for Goulds customers. Could there possibly be more benefits for customers using the new TaperBore™ PLUS? In fact there are two (2)!

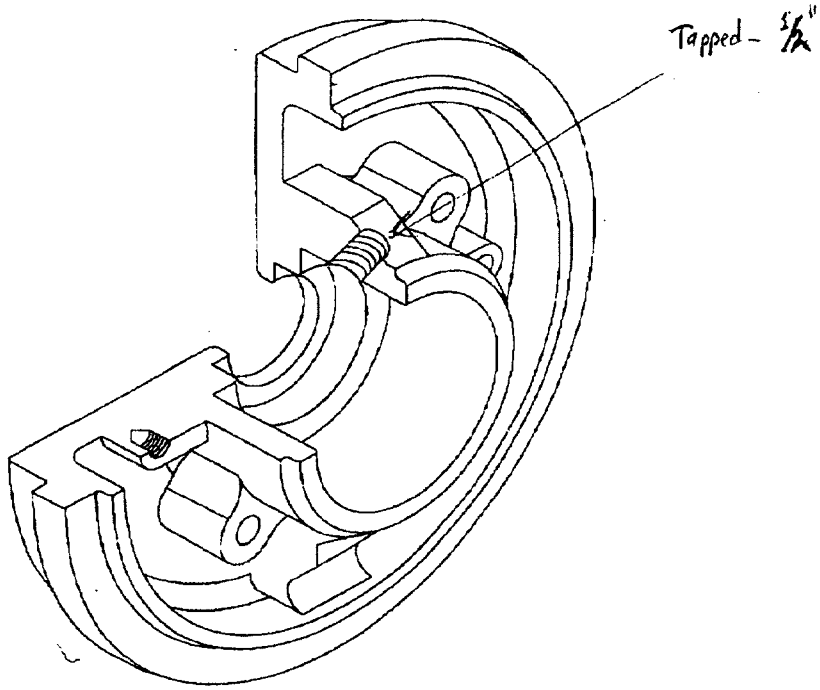
(1) The TaperBore™ PLUS is designed to do all of the above without flush. That means no external water or other liquid is required to lubricate seal faces. No CPI flush tube or pipe is required. This is not true for all services but for many the TaperBore™ PLUS works great without flush.

(2) The last feature of the new TaperBore™ PLUS is that its self draining. Self-draining is important so that liquid residue and particles that could solidify during a shut down drain away from the mechanical seal. (Without draining before the next pump start-up the seal could bind or wear due to the residual solids accumulating in and around the mechanical seal.)

By now you've most certainly concluded that the patented TaperBore™ PLUS provides the best seal environment for conventional or cartridge single mechanical seals on many services. (Water to Benzene with up to 10% solids no flush, Paper stock 0-5%). After all that's what is was designed for. It can also be used effectively for cartridge double seals.

Figure 2

BigBore™ Seal Chambers

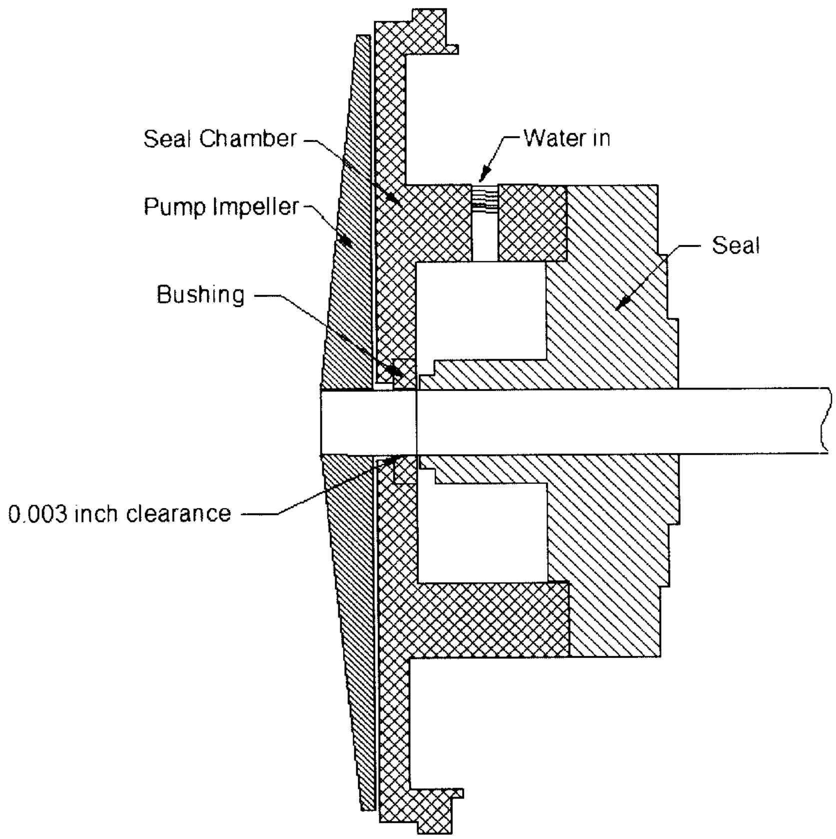


Designed specifically for mechanical seals. Large bore chamber provides increased life of mechanical seals through improved lubrication and cooling of seal faces. Mechanical seal environment should be controlled through use of CPI flush plans. Ideal for conventional or cartridge single mechanical seals in conjunction with a flush and throat bushing in bottom of seal chambers. Also, great for conventional or cartridge double or tandem seals.

BigBore™ with Internal By-pass

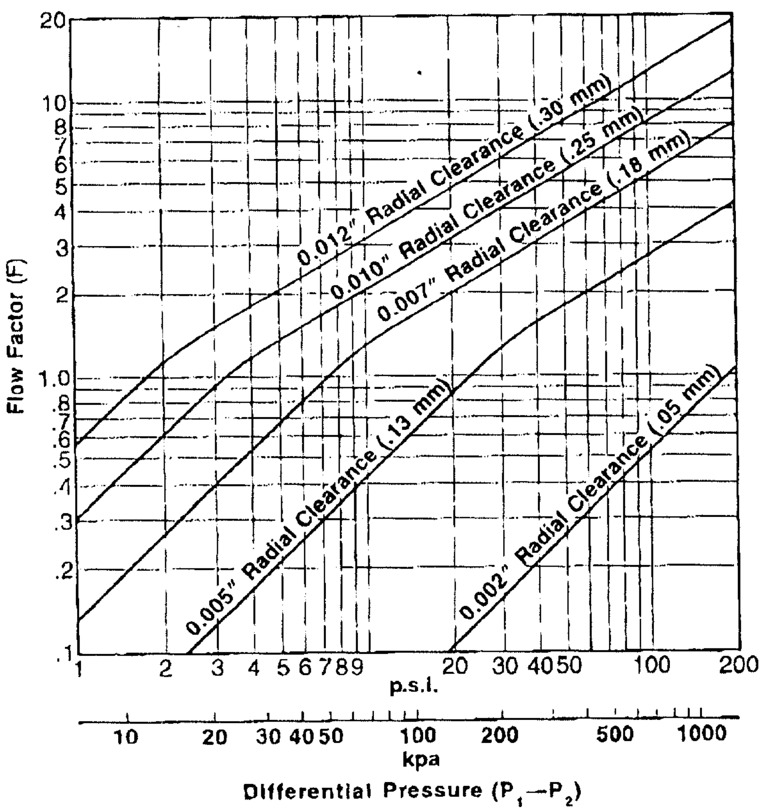
Provides internal circulation of liquid to seal faces. Use when external flush tubing or piping is not desirable.

Figure 3


Seal Chamber
Water in
Pump Impeller
Seal
Bushing
0.003 inch clearance

APPENDIX 2

Figure 4.37 Flow Rates for Close Clearance Bushings



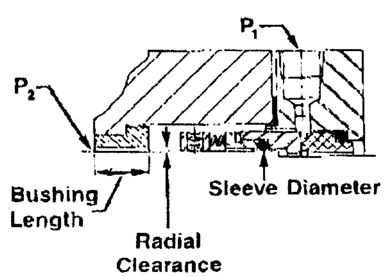
Notes for Figure 4.37

Basic Formula:
GPM = F x L x inch of shaft O.D.
LPM = F x L x mm shaft O.D. ÷ 6.7
for water at 70°F (20°C),
for oil multiply by 0.12

Where:
F = flow factor from graph
L = bushing length factor from table

Derived formula:
F x L = gpm ÷ inch shaft O.D.
(F x L = lpm x 6.7 ÷ mm shaft O.D.)

Example:
- Estimate the gpm (lpm) of flush required to achieve 15 ft/sec velocity at the seal chamber throat from Figure 4.36 for:
  Shaft size: 4"(102 mm)
  Radial clearance: 0.010"(25 mm)
- Flush required: 6 gpm(23 lpm)
- F x L = 6 gpm ÷ 4"
  = (23 lpm x 6.7 ÷ 102 mm) = 1.5
- If a bushing length of 1.000" (25.4 mm) is selected, then L = 1.00 from the table
- Calculate
  F = 1.5 ÷ L = 1.6 ÷ 1.00 = 1.5
- From the graph, a flow factor of 1.5 with a 0.010"(0.25 mm) radial clearance requires a ΔP of 5 psi (34 kPa).
- If the stuffing box pressure estimated from Section 7.2.1 is 45 psi (310 kPa), the estimated flush pressure required is 45 + 5 = 50 psi (345 kPa) in this example.



BUSHING LENGTH FACTOR		
Length		Factor (L)
inch	mm	x
.250	6.4	2.00
.375	9.5	1.60
.500	12.7	1.40
.625	15.9	1.30
.750	19.0	1.20
.875	22.2	1.10
1.000	25.4	1.00
1.250	31.7	0.90
1.500	38.1	0.80
1.750	44.4	0.75
2.000	50.8	0.70
2.500	63.5	0.65
3.000	76.2	0.60

Appendix 3.

Consolidation Recirculation Pump Comparison

10/10/05

	Desired Parameter	Existing Goulds Pumps	Vortex Type Pump	Diaphragm Pump (top Discharge)	Moyno Screw Feed Pump
Shaft seal flush water required	Minimal or no flush water into process	Yes – Flush water added to process	Packed seal (standard), or Double Seal with clean flush water to external drain or reuse, or slurry seal (no flush required)	No shaft seals required	Packed seal (standard) or Double Seal with clean flush water (recommended for this application) to external drain or reuse
Vulnerabilities which could cause pump failure	Minimum Vulnerabilities	Loss of mechanical seal flush water, high solids content, solid slugs entering pump, cavitation, or running at zero flow, pump vibration	Cavitation, or running at zero flow for long periods, pump vibration	Check valve failure	Running at zero flow, high concentrations of sand grit in the slurry could wear out rotor and stator
Blocked Suction –Zero Flow?	Not affected	< ½ hr	< ½ hr	Not affected	< 5 min
Accepts large solids	Yes – ½" max	No	Yes	Yes-up to 2"	Yes
Compatible Material Available	Yes	Yes	Yes	Yes	Yes
Flow Control Features	No preference	VFD	VFD	Air Pressure Control	VFD
Restricted Suction – Cavitation Impact	Not affected	Medium to High	Medium	Not affected	Not Affected
Ability to flush	Yes	Yes	Yes	No	No

backwards through pump to clear blocked suction					
Piping rework required if existing pumps are replaced	Minimal	None	Low to medium	Low to medium	Extensive piping rework would be required
Electrical Rework	Minimal	Add VFD	Add VFD, would require increase in motor breaker and cable size	Add Shut down interface to air supply	Add VFD
Pump Wear Resistance	High	Medium	Medium	High	Depends on solids – grit type = low, mud type =high
% Solids Capability	>25%	5-10% max	Up to 50%	Up to 70% & 2" solids	Up to 70%
Noise Level	Low	Low	Low	High	Medium
Electrical Hp or Air Capacity	15 Hp or less	15 Hp	20+ Hp	80 SCFM (vent to off gas system or thru HEPA)	7.5 Hp
Approximate Cost			$7,000 to $9,000 (pump only)+ $3,000 (Double seal), or $4,000 (slurry seal)	$5,000 (Pump only)+ Portable Air Compressor +	$8,000 (pump only) + $3,500 (Double seal)
Availability	<4 weeks	NA	4-6 weeks (pump)	3 weeks (pump)	8-10 weeks (pump)
Vendor		C. H Spencer Salt Lake City, UT	Davidson Sales & Engineering Salt Lake City, UT (801) 977-9200 (Chris)	Paramount Supply Boise, Id (208) 345-5432 (Travis)	Davidson Sales & Engineering Salt Lake City, UT (801) 977-9200 (Chris)
Manufacturer		Goulds	WEMCO	Warren-Rupp	MOYNO
Model No		Model MTX-3196	Model C 3x3 Vortex Pump	Sandpiper SA2-A-DV-5-II Viton Diaphragm	1L10-CDQ3AAA

				CI Housing Bottom Discharge	
Technical Choice			2	1	